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Those who care about CCS—Results from a Japanese survey on public understanding of CCS-

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ABSTRACT

In order to assess the present status of the general public's awareness and opinion on Carbon Capture and Storage (CCS) and to analyze attributes of groups who have different opinions on CCS, a Japanese social survey was conducted in 2015. The results of the survey showed that the majority of the Japanese general public did not know much about CCS but were interested in CCS without any opinion on CCS as a part of climate policy portfolio. In terms of implementation of CCS, the Not in My Backyard (NIMBY) perception on CCS influenced opinions, while about half of the respondents did not have clear opinions on a hypothetical plan of implementing offshore CCS near their home.

Respondents were categorized to four groups, who were consistently positive, consistently negative, changeable or fundamentally indifferent to CCS, and the points of communication for each group were discussed to get a consensus on CCS policy and implementation. The survey found that some of the characteristics of indifferent people toward CCS had a low level of consciousness regarding concerns on climate change issues and politically passive on national political issues. Required information to communicate CCS issues for each group were identified by the analysis. The results of our analysis highlighted the importance of informing the Japanese general public about the technological maturity, positive and negative impacts or risks of CCS, and the necessity of climate change mitigation action in communicating the issues surrounding CCS implementation.

1. Introduction

As Carbon Capture and Storage (CCS) has been developed as one of the key technologies in the energy-climate community in the world, the Japanese government has promoted the R&D of CCS. This has made it an important climate change measure for achieving an 80% greenhouse gas (GHG) emission reduction by 2050 according to the 5th Strategic Energy Plan (The Government of Japan, 2018). The Tomakomai CCS demonstration project has been carried out to demonstrate the technical feasibility of the full CCS chain. It started injecting CO_2 into an offshore geological reservoir by an extended reach drilling well since 2016. The Ministry of the Environment has initiated two important CCS related projects (Sustainable CCS Project and the Project for Investigation of Potential CO_2 Storage Site) since 2014.

While some CCS projects have been achieving positive results in Japan, the general public still has little awareness about the technology. This engenders a potential problem in developing communication strategies especially for local communities in the future. We dedicated our efforts to grasp the public perception of CCS via several social surveys and repeatedly found that there were a large numbers of people who have no specific opinion on CCS and a lower amount of people who do not care about CCS in a positive or negative way. That is they remain indifferent.

In December of 2015, a social survey using a representative Japanese sample was conducted and analyzed in order to understand thestatus of general public awareness and opinions on CCS and to analyze the attributes of groups who have differing opinions. The objective of this paper is: 1) to introduce the assessment of public acceptance of CCS from the 2015 survey; 2) to examine factors which affect the perceptions and opinions about CCS; and 3) to discuss the attributes of the groups who do not have a strong opinion about CCS in various ways. In other words we examine the attributes of the groups who are consistently positive, consistently negative, changeable or fundamentally indifferent to CCS. Although public perception and acceptance of CCS technology has been studied in various aspects by many researchers to date, the attributes of those groups of people,

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especially those who are indifferent to CCS has not been fully analyzed. Yet, even indifferent people would also reap the benefits of future CCS projects and pay the associated costs indirectly when CCS is deployed at the large scale. Therefore, we intend to provide usefull information relevant to effective communication to those people who probably exist worldwide through the analysis of their attributes.

2. Literature

Most previous surveys and studies on the public acceptance of CCS were carried out for the following two key purposes:

1) to assess the status of acceptance or acceptability of CCS at the national or regional revels; and/or
2) to identify factors and/or elements which influence public acceptance of the technology.

Some of the previous studies cover only one of these two purposes but many of them cover both.

Seigo et al. (2014) conducted a review to compare major CO_2 emitting counties in terms of the number of CCS projects and of public perception of studies conducted to date. There was no direct correlation observed between the number of CCS projects and the amount of CCS perception studies conducted in these locations. Among the 14 key CO_2 emitters identified in the review, the largest number (i.e. 14) of CCS public perception studies were conducted in the Netherlands where only two large-scale CCS projects had been carried out. Switzerland and the United States of America (USA) follows the Netherlands in terms of the number of CCS perception research cases. Seven studies were identified in both counties while there was a significant difference in the number of CCS projects. While the largest number of CCS projects (i.e. 23 projects) among the 14 countries were or had been carried out in the USA, no CCS projects were identified for Switzerland at the time of the review. One of the reasons that Netherland had a large number of CCS public perception studies can be it reflected the interest of public and scientists in CCS increased by the Barendrecht CCS project (Ashworth et al., 2015). The largest CO_2 emitter, China, followed the USA in terms of the number of CCS projects but only one perception study was identified (Chen et al., 2015). China public perception study may be less required because of the difference of political system. Similar to Switzerland, three CCS perception researches were identified in Japan although no large-scale CCS project had been carried out at the time of the review.

Ashworth et al. (2015) studied developments in public communications on CCS and reviewed a range of national or regional attempts to understand public perception, knowledge and awareness of CCS. These attempts ranged from large-scale surveys to more targeted surveys and focus groups. The first comparative assessment of public perception of CCS, identified and reviewed by Ashworth et al. (2015), was conducted by a group of researchers from Massachusetts Institute of Technology (USA) and the University of Cambridge (United Kingdom (UK)) in 2003–2005 (Curry et al., 2007, 2005; Curry, 2004). This survey also included Japan and Sweden and was repeated periodically and an international comparative study was conducted (Reiner et al., 2006).

In Japan, surveys to assess public awareness and acceptability of CCS were conducted repeatedly in 2003 and 2010 (Itaoka et al., 2011, 2005). In more recent years, annual surveys to monitor public awareness were conducted in the UK from 2013 to 2017 (Kraeusel and Möst, 2019; Ashworth et al. (2015). These series of surveys identified changes in public awareness of CCS and its environmental impacts over the study periods. The results suggested that a noticeable increase in public awareness was observed during the study period but public knowledge on the environmental impacts of CCS remained poor. Further, some factors which influence public acceptability and support on CCS were identified in the study. The factors which influence public acceptability of CCS included the amount of public capital investment and distance to infrastructure in relation to respondents' locations.

The 2011 the Special Eurobarometer 364th edition (Eurobarometer, 2011) completed a more recent national scale study on the public awareness of CCS. The survey was conducted across 12 European member states where CCS had at least been considered. The public awareness was still relatively low except in the Netherlands where a controversial Barendrecht project attracted public attention (Ashworth et al., 2015). The failure of the Barendrecht project implies the importance of public trust to project implementer and any kind of miscommunication between public surrounding the project site and project implementers can happen without the trust between them (Feenstra et al., 2010). The problem like that happened in the Barendrecht should be avoided by appropriate social site characterization and public engagement because a large amount of efforts on either sides would be wasted. A national survey in Australia, which is a country where CCS projects have been actually conducted, in 2011 (Jeanneret et al., 2014) and 2013 (The Government of Japan, 2018) also showed relatively low public knowledge of CCS and much lower support for CCS compared to most renewable energy sources (Ashworth et al., 2015).

Although many of the previous surveys were conducted in western countries, there are some Asian studies. For example, a large-scale national survey of public perceptions of CCS in China (Chen et al., 2015). The participants of this survey were skewed towards a relatively highly-educated population (i.e. over 93% with a college or university degree), however the results were very similar to the previously discussed surveys conducted in western counties. The percentage of the respondents who had never heard of CCS was very high (over 61%) compared to other renewable energy technologies. While opposition was not particularly high compared to other renewable energy technologies, the support was the lowest among renewable energy technologies and over 35% of respondents were indifferent to CCS.

In general, most previous studies did not differentiate respondents according to their attributes or discuss the relationships between group attributes and their acceptance of CCS. One of a few studies which extended their analysis to analyze factors that are relevant for the acceptability of CCS was a review of 42 articles on the public perception of CCS by Seigo et al. (2014). They used 11 elements of the energy technology acceptance framework identified by Huijts et al. (2012) who built a framework that pulls together different psychological theories and concepts that have been applied in acceptance research of sustainable energy behavior. These 11 elements are: 1) acceptance/attitude; 2) knowledge; 3) experience; 4) trust; 5) fairness; 6) affect; 7) perceived costs; 8) perceived risks; 9) perceived benefits; 10) outcome efficacy; and 11) problem perception. Their review identified "knowledge" and "problem perception" were included in majority of the studies they reviewed, followed by "perceived risks," "perceived benefits" and "trust." The results of this review concluded risk and benefit perceptions are two of the main predictors of the acceptability of a technology, confirmed by many reviewed studies. Trust in stakeholders was another influential variable that can have a direct effect on acceptance.

Although public perception and acceptance of CCS has been studied by many researchers as discussed above, the attributes of people in relation to the perception of CCS has not been discussed in detail. Some researchers analyzed the relationship between the level of climate change concern and higher risk or benefit perception (therefore the level of acceptance, (Wallquist et al., 2010); and (Oltra et al., 2010); and (Kraeusel and Möst, 2019)). One of the other sets of values previously studied in relation to public acceptance was people's belief in susceptibility of a chain/web of ecosystems. That is belief to protect the environment from any interference since the environment has own bioethical values. Tokushige et al. (2007) and Wallquist et al. (2012) identified tampering with the subsurface as a significant predictor of risk and/or benefits perception.

None of these studies covered the attributes of groups who are

Table 1
Administration of the survey.

Survey period	December in 2015
Survey area	Japanese region
Survey respondents	General public aged 20 or older living in Japan
Survey method	Random walk method[a]
Sampling method	Two stage stratified sampling[b]
Response rate	46.6%
Number of valid responses	548

[a] Surveyors start at one address in the area of the sampling point and then randomly select another map address to find the next participant.
[b] The panel was representative of the demographic characteristics (gender and age) of the Japanese population.

fundamentally indifferent to CCS and the attributes of groups who care about CCS. The national survey in China (Chen et al., 2015) presented the survey results including people who have no opinion on CCS. However, the study simply considered that indifference was caused by lack of knowledge about the technology and the attributes of people indifferent to CCS have not been investigated in detail.

3. Survey design and descriptive statistics

The survey was conducted in December 2015, targeted at the general public aged 20 or older living in Japan. The information on administration of the survey is summarized in Table 1. The sample was collected using two stage stratified sampling and a random walk method, which is a method of random sampling that surveyors start at one address in the area of the sampling point and then randomly select another map address to find the next participant, to achieve better representativeness of the general population. The response rate was 46.6%, which is relatively high as a research survey, indicates acceptable? reasonable? representativeness of the population.

The questionnaire consisted of 5 parts (questions on respondents' characteristics, environmental issues, concern/interest and opinion on CCS, information requirements on CCS, and preferred composition of power generation) including the provision of some information on CCS.

Descriptive statistics on demographic attributes, daily behavior and recognition of the CO_2 reduction target in 2030 by Japan, which is a topical statistic to measure how public follow the government's climate policy, are presented in Table 2. Respondents average age was 45.9, and about half (48.4%) of them were women. Their average years of education was 13.55 (university graduates: 28.2%).

About half of them (50.7%) answered how they voted in every election. More than half (62.5%) of the respondents joined in Internet communities such as SNS, but only 20.4% of them posted their opinions on their blog or SNS. With regard to the respondents' way of information gathering, "searching the internet" and "asking someone or gathering information from mass media (TV, newspaper, etc.)" was the most frequent response.

The Japanese government decided Japan's Intended Nationally Determined Contributions (INDC) such that the GHG emission reduction in fiscal year (FY) 2030 will be 26.0% when compared to FY 2013, in July 2015 (Ministry of Foreign Affairs of Japan, 2016). Although only 3.7% of the respondents knew both the settings of the target and its numerical value, about half of the respondents knew that the target had been set. As much as 38.1% of the respondents did not know both parts, nor did they understand the GHG emissions reduction target for 2030.

4. Results of survey

4.1. National assessment on public acceptance of CCS

4.1.1. Awareness of CCS

In the survey, the respondents were asked whether they had heard about CCS before receiving some basic information about CCS. Over one half (57%) of all respondents answered "No, I have never heard about it". One third of the respondents (33%) answered "I have heard about it before", only 9% responded "I know about it".

The awareness of CCS had significantly increased compared to 2003 (Itaoka et al., 2005) and 2010 (Itaoka et al., 2011) (Fig. 1), although it was the least recognized among other technologies used as global warming mitigation measures such as solar energy, wind energy, nuclear power and so on (Fig. 2).

Fig. 3 shows the answer to the question about whether respondents had concerns or were interested in CCS, assessed after basic CCS information was presented. The majority, 43.8% of the respondents indicated their concern or interest in CCS, and 22.1% of them did not have any concerns or interest regarding CCS. The remaining respondents (34.1%) did not express their opinion (i.e. can not say).

4.1.2. Opinions on implementation of CCS

Respondents were also asked about their opinion on CCS implementation in Japan as part of a climate change mitigation policy portfolio. We found that more than half of the respondents (54.4%) did not have an opinion toward CCS as part of a climate policy portfolio. More than one third, 36.1% of the respondents answered that they

Table 2
Descriptive statistics on demographic attributes, daily behavior and recognition of Japanese CO_2 reduction target in 2030.

Survey categories	Respondents' characteristics
Average age	45.9 years old
Percentage of women	48.40%
Average years of education	13.55 years(University graduates: 28.2%)
Daily behavior:	50.7%
Vote in every election	
Join in meetings or events in local community	42.7%
Join in virtual community (SNS, etc.)	62.5%
Post on blog or SNS	20.4%
Have expressed opinions in some way other than elections	3.3%
Way of information gathering:	47.3%
First, search the Internet:	
First, ask someone or gather information from mass media (TV, newspaper, etc.)	46.8%
Do nothing	4.2%
Recognition of Japanese CO_2 reduction target in 2030	
Knows the target has been set and knows its numerical value.	3.7%
Knows the target has been set but does not know its numerical value.	51.7%
Does not know the target has been set but knows its numerical value.	6.6%
Does not know the target has been set and does not know its numerical value.	16.5%
Don't know it at all (don't know anything about the target).	21.6%

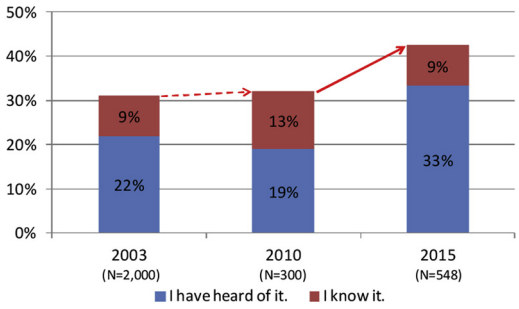

Fig. 1. Awareness of CCS compared to 2003 and 2015.

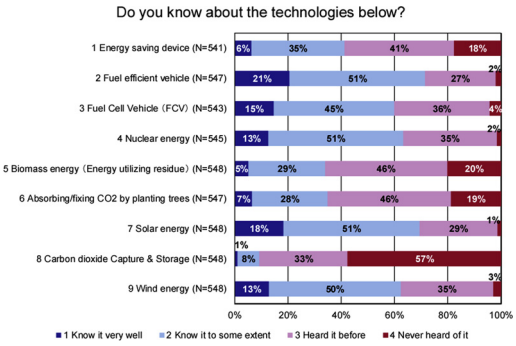

Fig. 2. Awareness of CCS compared to other GHGs reduction technologies.

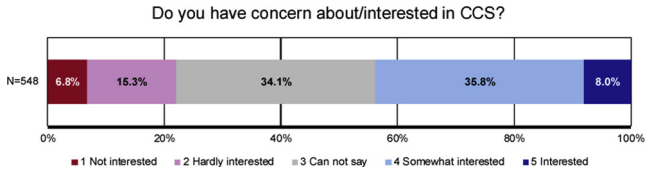

Fig. 3. Respondents' concern about/interest in CCS.

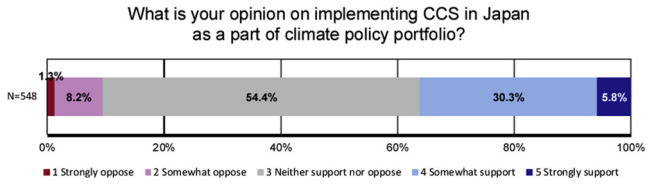

Fig. 4. Opinions on CCS implementation as a part of climate policy portfolio.

would support it, and 9.5% of the respondents answered that they were against it (Fig. 4). When it comes to implementing more concrete offshore CCS plans (the plans were explainedas hypotheticalin the questionnaire), negative opinions increased. This is a typical appearance of the Not in My Back Yard (NIMBY) type perception (Lake, 1993). Nevertheless, about half (54.4%) of all respondents did not present any opinion on the implementation of CCS (Fig. 5).

In terms of proximity of the CCS site, less people opposed implementing "CCS offshore at tens of kilometers off the coast near Japan" (Fig. 5) than "CCS offshore at a few kilometers away from the closest shore to their house (Fig. 5)." This means that NIMBY perception again influenced opinions on CCS implementation in a negative way reflecting proximity of the CCS sites. This finding is supported by another crosstab analysis, which showed that respondents who did not take any action on local issues (respondents who answered "Do nothing" for the question on the willingness towards taking action on national issues: If there was a plan to construct the facility which is useful to the society but might cause a problem to the area you live in, what actions would you take?) tended to answer "neither support nor oppose" to a hypothetical plan of implementing offshore CCS near their house. Such a sub-group would represent the typical type of "indifferent" people toward CCS or any kind of climate change issues in Japan.

Cross-tab analyses between respondents' opinions and their attributes indicated that respondents who knew about CCS tended to have an interest and expressed supportive opinions toward it. Also, respondents who knew the Japanese government's decision regarding the GHG emission reduction target by 2030 and/or its numerical value tended to have concerns/interest in CCS and have clear (positive or negative) opinions about CCS. It appears the environmental awareness of respondents tends to influence people in having clear opinions toward CCS.

Fig. 6 shows the result of another cross-tab analysis of concerns/interest in CCS and opinions on CCS implementation as part of a climate policy portfolio. The respondents who had more concerns/interest tended to have opinions which support CCS as part of a climate policy portfolio. However, opinions to oppose CCS including "somewhat oppose" and "strongly oppose" were indicated by a certain number of respondents irrespective of having concerns/interest in CCS.

4.2. Factors shaping opinion on energy and environmental issues including CCS

4.2.1. Identification of influential factors

We conducted exploratory factor analysis to identify the "latent" factors shaping opinions on energy and environmental issues including CCS. Factor analysis is a statistical technique which uses the correlations between observed variables to find common latent factors and the structural linking of factors to observed variables. Factor analysis was selected since it allows exploration of the underlying structure of a collection of observed variables. In this study, the questions on "If I were in charge of climate policy in government, I will use …. technology" and the 25 questions on opinion on energy and environmental issues including CCS prepared were used for factor analysis. To conduct factor analysis, missing data were replaced with mean values. Factors were extracted by maximum likelihood solution. The rotation of factor axis was carried out by Promax rotation method. The number of factors was decided using a Scree plot (a graph in which eigenvalues are plotted in the sequence of the principal factors) (Cettell, 1966). The number of factors was chosen at the point before a sharp-decrease trend of the plot level was observed (Cettell, 1966). It was confirmed for the factor chosen to have an eigenvalue greater than 1. The result of the Scree plot shows that the number of factors obtained equaled four. Table 3 provides further results of this analysis by showing the factor-loading matrix.

The four factors obtained by the factor analysis are interpreted below. The labels for each factor was determined based on subjective

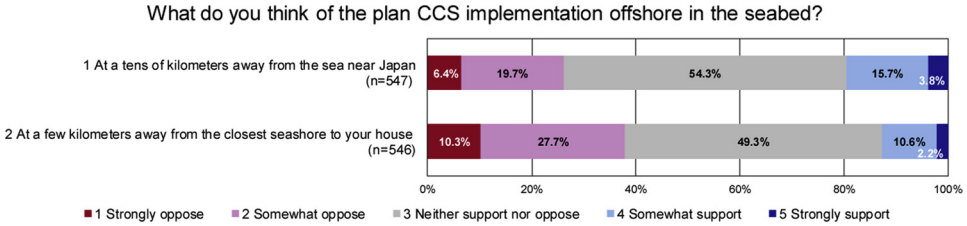

Fig. 5. Opinions on CCS implementation in the seabed offshore.

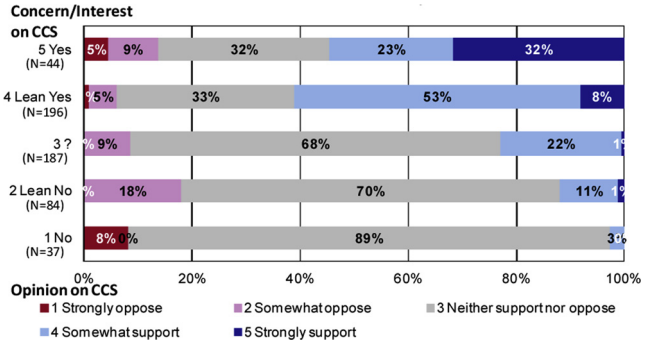

Fig. 6. Cross-tab of concern/interest and opinion on CCS.

assessment of the similarities in the survey questions associated with each loading factor:

Factor 1: Pro renewable and anti-climate change (respondents' preference of renewables and energy saving technologies)

Factor 2: Environmental responsibility (respondents' understanding of responsibility for climate change and tendency not to take risk by using new technologies)

Factor 3: Perceptions of risk (respondents' perception of risk on technology including concern about environmental impacts and risks caused by injection of CO_2 and possibility of leakage and negative attitude to use nuclear) is this about perceptions of risks more generally not just CCS?

Factor 4: Source trustworthiness (respondent tendency to trust information sources and optimistic attitude toward new technologies to solve energy problems)

4.2.2. Factors that affect opinions on the implementation of CCS

To understand impacts of latent factors shaping opinions on energy and environmental issues identified in the previous section on the specific two questions about CCS implementation: "CCS implementation in Japan as a part of climate policy portfolio" and "CCS implementation offshore at a few kilometers away from the closest seashore to their house". We used the answers to those two questions as dependent variables and used factor scores of the latent four factors found in the factor analysis as explanatory variables. We confirmed the correlation of the four factors as reasonably low, enabling us to use them as independent variables. Fig. 7 shows the result of the regressions.

The explanatory scores (adjusted R squares) are moderate, 0.235 for the regression on CCS implementation in Japan as part of a climate policy portfolio, and 0.297 for the regression on CCS implementation offshore from the closest seashore to their house. Because we ignored the smaller factors - other than the four identified in the exploratory factor analysis - an unexplained part of dependent variable variation should exist. Therefore, a very good fit should not be expected. However, for the purpose of examining the influence of the four factors, this level of fit is sufficient.

According to the standardized coefficients of the regression, for the regression on CCS implementation in Japan as a part of climate policy portfolio, Factor 4, source trustworthiness had the largest positive impact (Std. Coef = 0.309) on respondents' opinions. Factor 3, perception of risk also gives a similar level but had a negative impact (Std. Coef = -0.293) on their opinion. This can be interpreted to mean that an optimistic attitude through trusts of information source to CCS as a new technology has a positive impact whereas the perception of risks of CCS has a negative impact. Factor 1, pro renewable and anti-climate change also produced a positive impact (Std. Coef = 0.182) on respondents' opinions. This implies that CCS was regarded within a similar category of renewables as anti-climate change technology. It is surprising that Factor 2's coefficient was statistically not significant indicating that it did not provide any impact on opinions. Factor 2, environmental responsibility support daily life efforts and renewable implementation but not CCS. "Climate policy portfolio" probably weakened the effect Factor 2.

For the regression on CCS implementation offshore from the closest seashore to their house, all independent variables are significant ($p < 0.01$) and nor surprising the largest impact (Std. Coef = -0.379) was provided by Factor 3 perceptions of risk. The perception of the risk of CCS was enhanced where a more concrete plan for the implementation of CCS closer to their house was presented. Factor 2, environmental responsibility provided a negative impact (Std. Coef = -0.243) and Factor 4 provided a positive impact (Std. Coef = 0.250) on opinions at the same level. The negative impact of Factor 2 implies that CCS is recognized as a new technology with a risk. The positive impact of Factor 1 appeared, however at a weaker level (Std. Coef = 0.149) compared to the previous question.

4.3. Group analysis based on opinions on CCS implementations

4.3.1. Groups and influential factors

To consider divergent opinions toward energy and environmental issues including CCS communication, we categorized respondents into 4 groups (described below) using results of the cross-tab analysis (Table. 4) and described the features of each group. We ignored those outside of Groups 1–4 (gray in Table 4) because the number of respondents was too small to use for statistical analyses.

- Group 1: Respondents who changed opinions on CCS implementation as a policy portfolio or as a project toward an unfavorable opinion (red in Table 4)
- Group 2: Respondents who didn't change opinions on CCS implementation "Strongly or somewhat oppose" (yellow in Table 4)
- Group 3: Respondents who didn't change opinions on CCS implementation "Neither support nor oppose" (green in Table 4)
- Group 4: Respondents who didn't change opinions on CCS implementation "Strongly or somewhat support" (blue in Table 4)

Fig. 8 shows the proportion of the groups and Fig. 9 shows the mean of factor scores produced through the factor analysis in the previous section by group. Factor scores are the latent scores for each respondent on each factor, indicating a respondent's placement on the factors. Mean factor scores of the groups provide information on the characteristics of the groups on the factors. For example, the larger mean factor score of Factor 3 Risk of CCS in a group indicates the groups perceive more risk in CCS implementation than other groups.

According to Figs. 8 and 9, Group 1 is the largest group and has medium mean factor scores of each factor compared to other Groups. This indicates that their opinions are based on a good balance of positive and negative factors and thus their opinions are sensitive to changes in the weight of factors when they express opinions toward a specific question. Since the absolute value of Factor 3 increased when expressing opinions on CCS implementation in the seabed offshore near their house compared to expressing opinions on CCS implementation as a part of climate policy portfolio according to the regression analyses, they changed their opinions in the negative direction. Group 2 is the smallest group and they have the largest factor score for Factor 3 and the smallest factor score (a negative score) for Factor 4. This explains the dominance of Factor 3 in their mind influenced their opinions consistently in a negative way toward both CCS implementation as a part of climate policy and CCS implementation in the seabed offshore near their house

Group 3 has about one third of the respondents who have very low mean factor scores (all negative scores) for all factors, which explains consistent neutral opinion to the two hypothetical CCS implementation plans. Their neutral opinions seem to derive from passive thinking rather than proactive thinking. Group 4 has 11% of respondents who have the feature of the largest mean factor score for Factor 4, representing a

Table 3
Factor-loading matrix of exploratory factor analysis to explore factors shaping opinions on energy and environmental issues.

	Questions	Factor 1	Factor 2	Factor 3	Factor 4
Pro renewable and anti climate change	If I were in charge of climate policy, I would use wind energy as technology for tackling global warming.	0.835	−0.111	0.042	−0.071
	If I were in charge of climate policy, I would use biomass energy as technology for tackling global warming.	0.765	−0.110	0.147	−0.056
	If I were in charge of climate policy, I would use solar energy as technology for tackling global warming.	0.730	−0.040	0.087	−0.004
	If I were in charge of climate policy, I would use fuel efficient vehicle as technology for tackling global warming.	0.726	−0.001	0.000	0.035
	If I were in charge of climate policy, I would use energy saving device as technology for tackling global warming.	0.690	0.101	−0.114	−0.116
	If I were in charge of climate policy, I would use absorbing CO2 by planting trees as technology for tackling global warming.	0.682	0.072	0.095	−0.042
	If I were in charge of climate policy, I would use fuel that emits less CO2 as technology for tackling global warming.	0.617	0.049	−0.148	0.057
	If I were in charge of climate policy, I would use CCS as technology for tackling global warming.	0.381	−0.161	−0.361	0.329
Enviromnetal responsibility	I think "I have no concerns about an influence of global warming to Japan."	0.049	−0.763	0.106	0.080
	I think "I doubt if global warming is really happening."	0.066	−0.732	0.096	0.079
	I think "It is difficult for Japan to reduce more CO2 emissions as it has already reduced compared to other countries."	−0.057	−0.552	0.266	0.300
	I think "Each one of us should make an effort to reduce CO2, which is a cause of global warming, emitted in our daily life."	0.006	0.459	−0.010	0.336
	I think "Not reducing CO2 emissions means that we just shift the responsibility onto the next generation."	0.066	0.459	0.171	0.196
	I think "Utilization of renewable energies should be promoted as soon as possible because fossil fuels are limited."	0.068	0.442	0.096	0.261
	I think "Most of CO2, which increased after the industrial revolution, were emitted from developed countries, therefore the developed countries are responsible for global warming."	−0.043	0.410	0.128	0.246
	I think "I want to prioritize safety more than anything else when I use new technologies."	0.088	0.393	0.174	0.158
	I think "I take some risks if there is something that I really want."	0.071	−0.383	−0.118	0.059
	I think "I have a distrust of scientists who promote specific technologies."	0.054	−0.381	0.370	−0.112
	I think "I am relatively interested in the environmental problem."	0.205	0.332	−0.019	0.246
Perceptions of risk	I think "I do not think that injecting something into the ground by humans is a good idea."	0.093	−0.015	0.699	−0.200
	I think "I worry that CO2 may be leaked if we transport it for a long distance."	−0.043	−0.083	0.646	0.138
	I think "I worry that we just shift risks onto the next generation by implementing CCS."	0.092	0.151	0.620	−0.043
	I think "I worry about an influence in case of leakage of stored CO2."	0.098	0.155	0.607	0.122
	I think "The diffusion of CCS causes a delay of the diffusion of renewable energies."	−0.135	−0.239	0.571	0.258
	I think "CCS needs more energy than not implementing CCS."	0.060	−0.045	0.520	0.067
	If I were in charge of climate policy, I would use nuclear energy as technology for tackling global warming.	0.033	−0.233	−0.359	0.140
Source trustworthiness	I think "A primary cause of global warming is ozone layer depletion."	−0.123	0.063	0.124	0.574
	I think "CCS is effective measure to tackle with global warming."	−0.036	0.096	−0.363	0.571
	I think "I trust in newspaper articles."	−0.109	0.044	0.149	0.487
	I think "Fossil fuels such as coal can be continuously used since CO2 emissions can be reduce by CCS."	−0.076	−0.324	−0.096	0.486
	I think "I worry about exhaustion of petroleum in the future."	−0.023	0.097	0.065	0.429
	I think "I believe what the government and officials say."	0.014	−0.323	−0.106	0.382
	I think "I worry whether we can use enough energy in the future at the same price as the present price."	0.142	0.213	0.056	0.368
	I think "Society should adopt new technologies as much as possible."	0.152	−0.084	−0.013	0.355

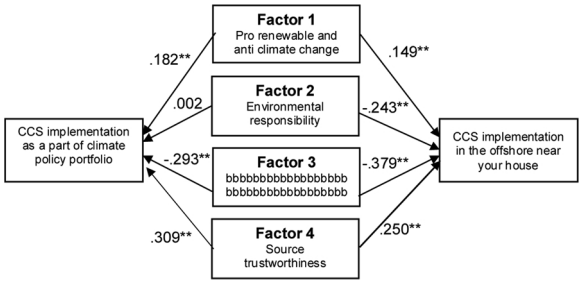

Fig. 7. Regression analysis on influence of four factors on opinions of CCS implementation (N = 450).
Note) **: significant level below 1%, *: significant level below 5%.

tendency to trust information sources and optimistic thinking toward new technology.

4.3.2. Attributes of the groups

In order to find demographical,behavioral andknowledge-based attributes for each group, cross-tab analyses with statistical tests (Pearson's chi-square) were conducted on the answers to demographic andbehavioral questions by group. As for demographical attributes, statistical tests indicated no significant feature exist with regard to age, gender, education or income. As for behavioral andknowledge attribute, statistical tests found some differences among the groups. The results of cross-tab analyses indicated a statistically significant difference among groups, as shown in Figs. 10–14.

For behavioral attributes, voting behavior at elections is significantly different (Fig. 10). Group 3 tends to vote less. Only 41% in Group 3 always go to the polls while 64% in Group 4 always go to the polls. Willingness toward political participation is also different. Group 4 tends to be the most active while Group 3 tends to be the most passive. The majority, 62% in Group 4 take some action toward national policies with which they are concerned, while only 35% in Group 3 take some action (Fig. 11). For a plan to construct a facility which is useful to the world but may cause a problem to the area in which respondents live (construction plans of a potential NIMBY facility), 78% in Group 4 take some action while only 55% in Group 3 take some action (Fig. 12). Group 2 is the second most active and Group 1 is the second least active for such plans.

For knowledge attributes, knowledge and recognition of climate change (global warming) issues are different among Groups. 41% in Group 1, 49% in Group 2 and 48% in Group 4 recognize that global warming is a serious problem and an urgent countermeasure is required (Fig. 13). Meanwhile, 29% of Group 3 recognize global warming in the same way. The proportion of respondents who have negative recognition on climate change such as "There is not clear evidence of global warming so that survey and research is required before making a countermeasure" and "There is no evidence of global warming" is the smallest in Group 4 and largest in Group 3 (Fig. 13). In terms of knowledge of the Japanese CO_2 (GHG) emission reduction target by 2030, more than 60% in Group 1, 2 and 4 knew the emission reduction target has been set by the government, but only 38% in Group 3 were aware of this (Fig. 14). Knowledge on CCS and interest in CCS differs among Groups. More than 20% in Group 4 knew CCS to some extent, while only 8–12 % of the other groups knew CCS to the same extent (Fig. 15). The proportion of respondents who were interested in CCS after information on CCS was provided in the questionnaire was very different (Fig. 16). 78% in Group 3 and 52% in Group 1 were somewhat interested or interested in CCS while 39% in Group 2 and 23% in Group 3 were somewhat interested or interested in CCS.

4.3.3. Groups and requested information

Finally, we examined further information needed for respondents to make more certain judgements on CCS implementation by asking respondents about any insufficiencies in the information provided as part of the questionnaire. Table 5 shows the ratio of respondents asking for more information in twenty specific topics relevant to CCS. The shaded columns indicate the ratio of respondents who requested further information, which is statistically different among groups.

The most requested information was information on who bears the cost of CCS. About 50% of respondents requested this information. The requested ratios were not statistically different. The cost of CCS was also evenly requested across the groups by 36% of respondents.

Information on the degree of maturity of CCS technology was requested by Group 1 (42%) and Group 2 (49%). The reason why CO_2 stayed underground post-injection was requested especially by Group 2 (43%). Information related to risk of CO_2 injection and storage was largely requested by Group 1 and Group 2. Information on impacts to underground stratum when injecting CO_2 were requested by 41% of Group 1 and 51% of Group 2. Information on impacts to the surrounding area when CO_2 leaks from the storage site was requested by 48% of Group 1 and 38% Group 2. Information on impacts to storage in the case of an earthquake was requested by 47% of Group 1 and 43% Group 2. Information on who is responsible (and how) for storage sites over a long period of time was requested by 51% of Group 2. Group 3 tends to be the least demanding of additional information. Group 4 is also less demanding for additional information but seems to be more interested in the effectiveness and necessity of CCS than other groups. Information on how much CCS can contribute to reducing CO_2 in Japan was requested by 33% of Group 4, higher than the level of interest from the other groups.

4.4. Discussion

Awareness of CCS among the Japanese general public has increased from 2010 to 2015, however their understanding does not extend to specific details of CCS. As a result, more than 50% of respondents did not state a clear opinion regarding CCS implementation in Japan as a part of their preferred climate policy portfolio. When the survey was conducted at the end of 2015, interest in climate change in Japan increased due to the Paris Agreement, implemented prior to the survey.

Table 4
Cross-tab of opinions on opinions on CCS implementation as a part of climate policy portfolio and opinions on CCS implementation in the seabed offshore near their house (N = 546).

		Opinions on CCS implementation in the seabed offshore near their house		
		Strongly or somewhat oppose	Neither support nor oppose	Strongly or somewhat support
Opinions on CCS implementation as a part of climate policy portfolio	Strongly or somewhat oppose	47(8.6%)	4(0.7%)	1(0.2%)
	Neither support nor oppose	114(20.9%)	17131.3%)	11(2.0)
	Strongly or somewhat support	46(8.4%)	94(17.2%)	58(10.6%)

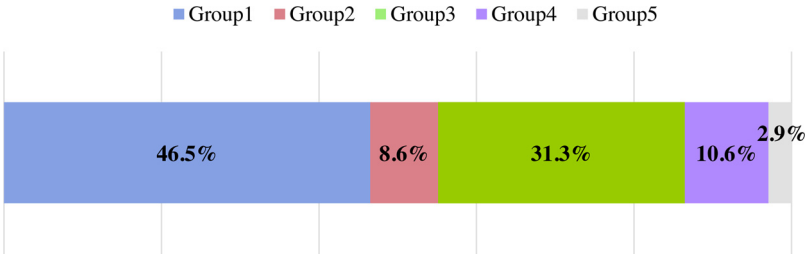

Fig. 8. Proportion of the groups based on cross-tab of concern/interest and opinion on CCS.

Therefore, awareness of CCS as a mitigation technology found in this survey reflected the public interest trend. We expect that the awareness and recognition of CCS by the public has not drastically increased because it seems there has been no significant event which would increase awareness or recognition. From the policy perspective, CCS is regarded as a potential climate technology option, and is referred to as a technology requiring development toward commercialization in the 5th Strategic Energy Plan (2018) (The Government of Japan, 2018). Since there is a possibility of the incorporation of CCS into the national energy policy portfolio, awareness and recognition of CCS by the public should be improved. It is important to clarify the point of communication to the general public for enhancing an appropriate level of understanding of CCS technology. We discuss the point of communication through the four groups which were identified with regard to respondent opinions toward CCS implementation,

Group 1 is the largest group, having 47% of respondents deciding their opinions based on a balance of four factors. It seems that this group's attitude represents that of the general public. They are sensitive to the perception of risk and benefits and therefore they change their opinion toward CCS implementation in a negative way when the implementation site is planned to be closer to their house. For Group 1, removing vague concerns on CCS is effective for good communication toward CCS implementation. The survey showed that this group needed more information on the technological maturity of CCS, the influences of CO_2 storage or CO_2 leakage, and also impacts from earthquakes on CO_2 storage sites. They also indicated that they wanted to know the economic effects for the local areas around CO_2 storage sites, which might improve the impression of CCS and enhance favorable perceptions toward it as a solution. The findings of the relationship between higher risk or benefit perception and attitude toward CCS highlighted in previous studies are generally applicable to Group 1.

Group 2 represented 9% of respondents who were influenced strongly by Factor 3, the risks of CCS. This group is consistently negative toward CCS implementation. With regard to communication about CCS, they need to be provided with information related to the risks of CO_2 injection and leakage as well as information on the necessity of CCS and its technical maturity. Their concerns about the environment, as identified in previous studies of public opinion links to their need for information on impacts on underground stratum when storing CO_2.

Group 3 is the second largest group, having 31% of respondents and seems to be the most difficult group to communicate with regarding

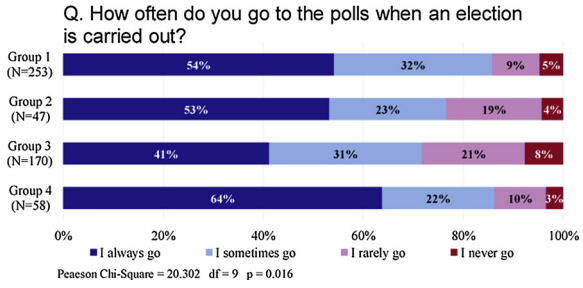

Fig. 10. Cross-tab of voting behavior at election and identified groups.

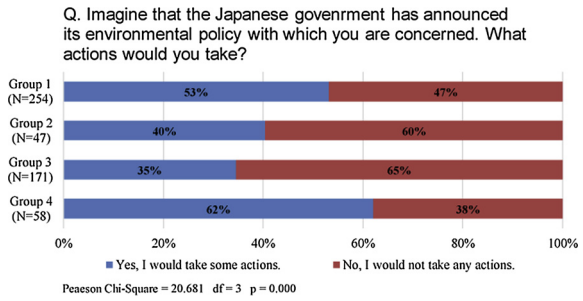

Fig. 11. Cross-tab of willingness to take some action toward national policies and identified groups (left).

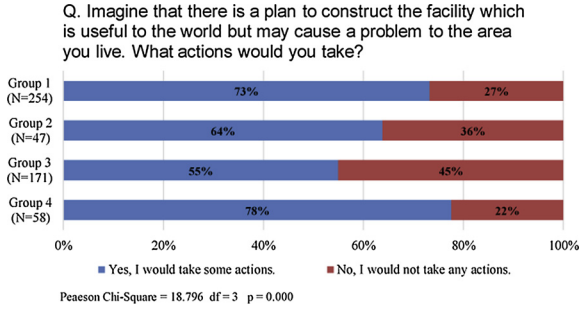

Fig. 12. Cross-tab of willingness to take some action toward plans of a potential NIMBY facility and identified groups (right).

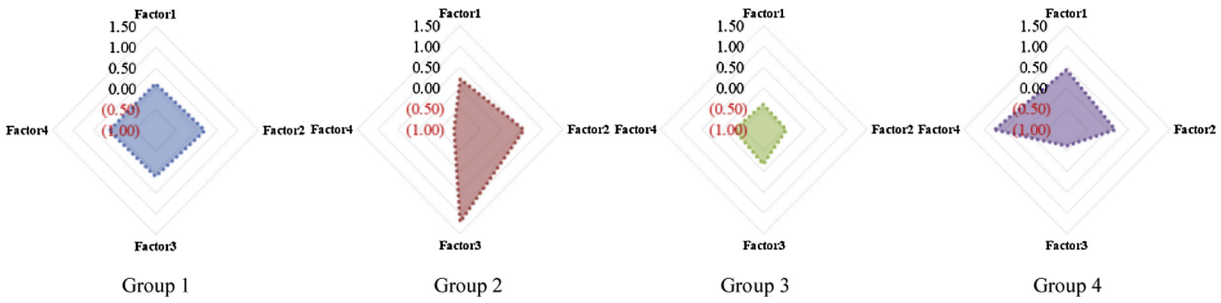

Fig. 9. Mean factor scores by the groups based on cross-tab of concern/interest and opinion on CCS.

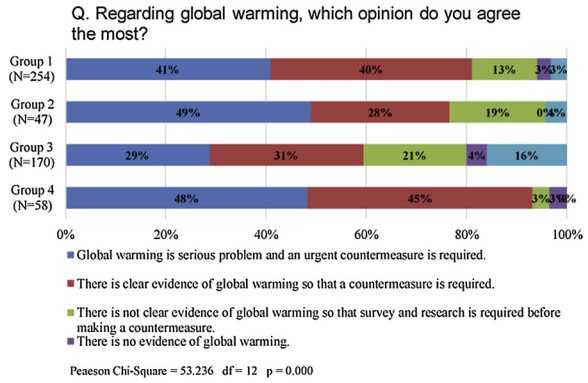

Fig. 13. Cross-tab of knowledge and recognition on climate change (global warming) issues and identified groups (left).

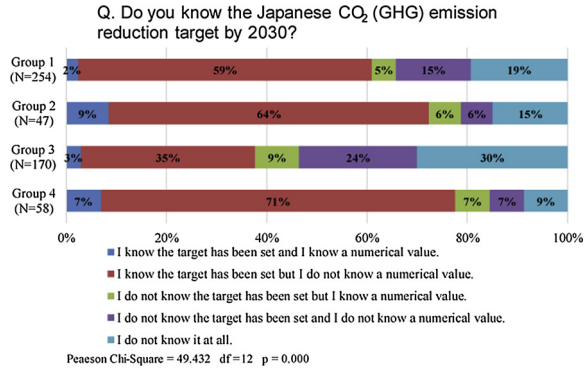

Fig. 14. Cross-tab of knowledge of the Japanese CO_2 (GHG) emission reduction target by 2030 and identified groups (right).

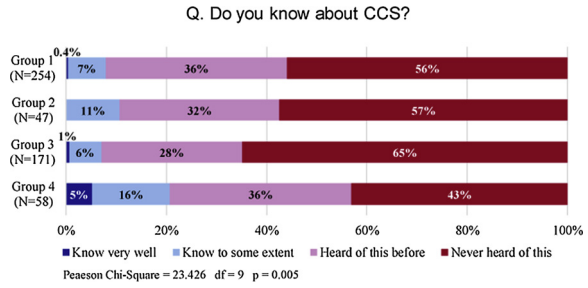

Fig. 15. Cross-tab of awareness of CCS and identified groups (left).

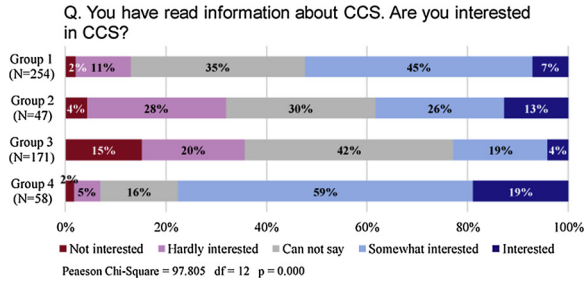

Fig. 16. Cross-tab of interest in CCS after information provision on CCS and identified groups (right).

CCS because they are largely indifferent to CCS and not influenced significantly by any factors. The attributes and appropriate communication method for this group have not been previously examined in other studies. This group is consistently neutral toward CCS implementation and do not seek additional information about the various aspect of CCS. Only information related to the cost of CCS was requested to the same extent as found in other groups. Providing cost information related to CCS with contextual information is likely to be a positive start to communicating CCS, because of the requirement to pay associated costs indirectly when CCS is deployed at the large-scale. In addition, information related to the actual site selection of CCS may be effective in stimulating interest in CCS, as this information is also sought at the same level as the other groups and can inform them about CCS implementation occurring in the real world.

Group 4 contains 11% of all respondents and is influenced by Factor 4, source trustworthiness, strongly. This group is consistently positive toward CCS implementation, but there is the possibility that their support will be changeable because some part of their understanding about CCS may be superficial, tending to believe more favorable information. They are more interested in how much CO_2 emissions can be reduced by CCS than other groups. Although they are less demanding for information related to the risks of CCS, it is recommended that a good balance of cost benefit and risk benefit information is provided, to allow them to develop a deeper understanding of various CCS aspects.

Finally, it can be said that it is necessary to build positive perceptions toward action for deep CO_2 emissions reduction to make people seriously face climate policy issues since Factor 1 is consistently influencing people's opinions.

5. Conclusion

In order to assess the status of the general public's awareness and opinions regarding CCS and to analyze the attributes of groups who have differing opinions, a Japanese social survey was conducted in 2015. The results of the survey demonstrated that the majority of the Japanese public did not have robust knowledge about CCS and also that they were generally interested in CCS but did not hold strong opinions as to its applicability as part of the climate policy portfolio. In terms of implementation of CCS, the NIMBY issue surrounding CCS influenced opinions, while about half of respondents did not have clear opinions on a hypothetical plan of implementing offshore CCS near their homes. Exploratory factor analysis identified four factors which shaped opinions on energy and environmental issues. These were: Factor 1, Pro renewable and anti climate change; Factor 2, Environmental responsibility; Factor 3, Perceptions of risk; and Factor 4, Source trustworthiness. Factor 3 generally accounted for respondents' NIMBY perceptions.

Respondents were categorized into four groups, who were: consistently positive, consistently negative, changeable or fundamentally indifferent to CCS. It was found that each group was influenced by the four influential factors differently in shaping their opinions on energy and environmental issues. The points of communication for each group were explored to gain a consensus on CCS policy and its implementation. The survey found that some of the characteristics of the respondents who were indifferent toward CCS had a low conscious level of concern toward climate change issues and were politically passive on national political issues. The authors would like to highlight not only the group which had changeable opinions and accounted for almost a half of respondents, but also the identification of an indifferent group which accounted for almost one third. For communication about CCS to the former we recommend the traditional approach clarifying risk and benefit details of CCS and removing technical uncertainly. For communication with the latter, we recommend providing cost information related to CCS with contextual information as an initial communication strategy, as they would be required to pay the associated costs indirectly when CCS is deployed at the large-scale.

For future studies, the attitude toward participation in energy-environment infrastructure policy of the indifferent group should be explored to determine whether their indifference can be influenced in real cases, as public understanding and involvement will be a key part of the energy program, however the current situation suggests a low level of voluntary public participation.

Table 5
Requested information by respondent to make more certain opinions on CCS implementation and ratio of respondents requested (N = 546).

	Requested information	Ratio of respondents to request				p-value
		Group1	Group2	Group3	Group4	
1	Cause and effect of global warming	17.7%	19.1%	18.1%	20.7%	0.959
2	CCS mechanism	22.8%	17.0%	15.2%	22.4%	0.238
3	The reason why CO_2 keep staying underground	36.6%	42.6%	30.4%	25.9%	0.172
4	The degree of maturity of CCS technology	41.7%	48.9%	29.8%	32.8%	0.024*
5	If CO_2 can be used for other purposes	28.7%	34.0%	17.5%	19.0%	0.017*
6	Necessity of CCS in the world	18.9%	17.0%	15.8%	22.4%	0.685
7	How much CCS can contribute to reducing CO_2 in Japan	27.2%	17.0%	16.4%	32.8%	0.014*
8	Necessity of CCS in Japan	26.0%	38.3%	18.7%	13.8%	0.008**
9	Cost of CCS	37.4%	38.3%	34.5%	34.5%	0.911
10	Who bears the cost of CCS (Cost allocation)	54.3%	46.8%	43.9%	51.7%	0.191
11	Economic effect in the area for storing CO_2	20.9%	8.5%	12.3%	13.8%	0.040*
12	How to select the site	33.9%	27.7%	31.6%	29.3%	0.798
13	Impacts to underground stratum when storing (injecting) CO_2	40.6%	51.1%	26.9%	27.6%	0.002**
14	Possibility of leakage of CO_2 from storage site	35.4%	36.2%	24.0%	17.2%	0.008**
15	Impacts to surrounding area when CO_2 leaks from storage site	48.4%	38.3%	31.0%	32.8%	0.002**
16	Impacts to storage are in case of an earthquake	47.2%	42.6%	33.3%	32.8%	0.019*
17	Who and how is responsible for storage site over a long period of time	36.2%	51.1%	32.2%	19.0%	0.005**
18	Relationship between storing CO_2 and the occurrence of earthquakes	33.1%	31.9%	19.9%	15.5%	0.003**
19	Preceding business	11.4%	10.6%	13.5%	15.5%	0.790
20	Tendency of CCS technologies in other countries	15.4%	17.0%	11.1%	19.0%	0.407

Note: The shaded columns indicate the ratio of respondents who requested further information, which is statistically different among groups. P-value is calculated by chi-square test. **: significant level below 1%, *: significant level below 5%.

Acknowledgement

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